

1 **What is claimed is:**

2

3 1. A method of improving data playback error performance in data
4 storage devices for storing data on removable data recording media, each data
5 storage device having multiple read/write heads for recording data to the media
6 during a write process and for playing back data from the media during a read
7 process, comprising the steps of:

8 (a) selecting a target error rate for recording data during the write
9 process, for one or more of the data storage devices; and

10 (b) for each data storage device, determining a dither value for each
11 head in the data storage device, wherein for each head, using the corresponding
12 dither value for the write process essentially provides said selected target error
13 for all the heads.

14

15 2. The method of claim 1, wherein in step (b) the write process for
16 each head comprises the steps of:

17 writing data blocks to the media; and
18 reading said data blocks from the media while introducing dither into the read-
19 back signal as a function of the dither value.

20

21 3. The method of claim 2, wherein in step (b) the write process for
22 each head further includes the steps of:

23 determining the error rate of the read data;
24 comparing the read error rate to the target error rate, and repeating
25 the write process if the read error rate is greater than the target error rate.

26

27 4. The method of claim 2, wherein in step (b), determining a dither
28 value for each head further includes the steps of, for each head:

29 (1) writing data blocks on a recording media, and reading said
30 data blocks from the media while introducing dither into the read signal as a
31 function of different dither values;

1 (2) measuring the error rate generated for each dither value;
2 and

3 (3) based on the measured error rates, determining a dither
4 value which generates an error rate at essentially the target error rate for that
5 head.

6

7 5. The method of claim 4 wherein in step (b)(3), determining said
8 dither value for a head further includes the steps of:

9 selecting a first dither value that generated an error rate below the target
10 error rate;

11 selecting a second dither value that generated an error rate above the
12 target error rate; and

13 performing interpolation between the first and second dither values, to
14 determine a dither value that generates an error rate at essentially the target
15 error rate for that head.

16

17 6. The method of claim 2, wherein step (b) further includes the steps
18 of, before determining said dither value for each head, prequalifying each head
19 and recording media for recording/playback operations, including the steps of, for
20 each head:

21 (1) writing data blocks to a first section of the media using a first dither
22 value in a first write process, and measuring the generated error rate for that
23 head,

24 (2) writing data blocks to the first section media using a second dither
25 value in a second write process, and measuring the generated error rate for that
26 head,

27 (3) if the measured error rate for each dither value is above the target
28 error rate, then repeating steps (1) and (2) for a second section of the media
29 using said first and second dither values, wherein if the measured error rate for
30 the each of the first and second dither values on the second section of the media
31 is above the target error rate, then that head is indicated as a faulty head.

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2 7. The method of claim 6, wherein in step (b)(3), if the measured error
3 rate for one of the first and second dither values on the second section of the
4 media is at or below the target error rate, but the error rate for another head is
5 above the target error rate for both the first and second dither values, then that
6 media is indicated as faulty recording media.

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8 8. The method of claim 2, further including the step of:
9 (c) in a write process for each head, writing data blocks with that head
10 while reading the data blocks and introducing dither into the read signal in the
11 head as a function of the determined dither value for the head.

12
13 9. The method of claim 8, further comprising the steps of:
14 (d) during a read process for each head, reading data with that head
15 without dithering.

16
17 10. The method of claim 8, wherein step (c) further includes the steps
18 of, upon detecting a block error while writing a data block on a section of the
19 media, re-writing that data block.

20
21 11. The method of claim 9, wherein re-writing that data block further
22 includes the steps of re-writing that data block on a different section of the media.

23
24 12. The method of claim 9, wherein re-writing that data block further
25 includes the steps of re-writing that data block using a different head.

26
27 13. The method of claim 9, wherein re-writing that data block further
28 includes the steps of re-writing that data block on a different section of the media
29 with a different head.

1 14. The method of claim 1, wherein the storage device comprises a
2 tape drive including multiple transducer heads, and the recording media
3 comprises magnetic tapes.

4

5 15. A method of improving data playback error performance in data
6 storage devices for storing data on removable data recording media, each data
7 storage device having multiple read/write heads for recording data to the media
8 during a write process and for playing back data from the media during a read
9 process, comprising the steps of:

10 (a) selecting a target error rate for recording data during the write
11 process, for one or more of the data storage devices; and

12 (b) for each data storage device, determining the amount by which to
13 artificially degrade the read signal during the write process for each head in the
14 data storage device to essentially provide said selected target error rate for all
15 the heads.

16

17 16. The method of claim 15, wherein step (b) further includes the steps
18 of, determining a dither value for each head in the data storage device, wherein
19 for each head using the corresponding dither value for the write process
20 essentially provides said selected target error rate for all the heads.

21

22 17. The method of claim 16, wherein in step (b) the write process for
23 each head comprises the steps of:

24 writing data blocks to the media; and

25 reading said data blocks from the media while introducing dither into the read-
26 back signal as a function of the dither value.

27

28 18. The method of claim 17, wherein in step (b) the write process for
29 each head further includes the steps of:

30 determining the error rate of the read data;

comparing the read error rate to the target error rate, and repeating the write process if the read error rate is greater than the target error rate.

19. The method of claim 17, wherein in step (b), determining a dither value for each head further includes the steps of, for each head:

(1) writing data blocks on a recording media and reading said data blocks from the media while introducing dither into the read signal as a function of different dither values, during the write process;

(2) measuring the error rate generated for each dither value;

and

(3) based on the measured error rates, determining a dither value which generates an error rate at essentially the target error rate for that head.

20. The method of claim 19, wherein in step (b)(3), determining said write dither value for a head further includes the steps of:

selecting a first dither value that generated an error rate below the target error rate;

selecting a second dither value that generated an error rate above the target error rate; and

performing interpolation between the first and second dither values, to determine a dither value that generates an error rate at essentially the target error rate for that head.

21. The method of claim 17, wherein step (b) further includes the steps of, before determining said dither value for each head, prequalifying each head and recording media for recording/playback operations, including the steps of, for each head:

(1) writing data blocks to a first section of the media using a first dither value in a first write process, and measuring the generated recording/playback error for that head,

1 (2) writing data blocks to the first section media using a second dither
2 value in a second write process, and measuring the generated
3 recording/playback error for that head,

4 (3) if the measured error rate for each dither value is above the target
5 error rate, then repeating step (1) and (2) for a second section of the media using
6 said first and second dither values, wherein if the measured error rate for the
7 each of the first and second dither values on the second section of the media is
8 above the target error rate, then that head is indicated as a faulty head.

10 22. The method of claim 21, wherein in step (b)(3), if the measured
11 error rate for one of the first and second dither values on the second section of
12 the media is at or below the target error rate, but the error rate for another head
13 is above the target error rate for both the first and second dither values, then that
14 media is indicated as faulty recording media.

16 23. A data storage device for storing data on removable data recording
17 media, comprising:

18 multiple read/write heads for recording data to the media during a
19 write process and playing back data from the media during a read process; and
20 a controller for controlling recording/playback operations with the
21 heads, wherein the controller is configured to artificially degrade the read-back
22 signal for each head during a write process to essentially provide a selected
23 recording target error rate for all the heads.

24. The data storage device of claim 23, wherein to degrade the read
25 signal the controller is further configured to introduce dither into the read-back
26 signal during a write process for each head as a function of a dither value
27 selected for that head, such that all heads provide essentially said selected target
28 error rate.

1 25. The data storage device of claim 24, wherein the controller is
2 further configured for the write process for each head to write data blocks to the
3 media, and read-back said data blocks from the media while introducing dither
4 into the read-back signal as a function of the selected dither value for the head.

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6 26. The data storage device of claim 25, wherein the controller is
7 further configured to the write process for each head to determine the error rate
8 of the read-back data, and to compare the read error rate to the target error rate,
9 and repeat the write process if the read error rate is greater than the target error
10 rate.

11

12 27. The data storage device of claim 25, wherein a dither value for
13 each head is determined by writing data blocks on a recording media and
14 reading back said data blocks while introducing dither into the read-back signal
15 as a function of different dither values during the write process, measuring the
16 error rate generated for each dither value, and based on the measured error
17 rates, determining a write dither value which generates an error rate at
18 essentially the target error rate for that head.

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20 28. The data storage device of claim 25, wherein the controller is
21 configured to read data from the recording media during a read process without
22 dithering the head read signal.

23

24 29. The data storage device of claim 28, wherein the controller includes
25 a dither circuit coupled to a read/write signal path in the storage device via a
26 switch, wherein the dither circuit provides a dither signal based on the dither
27 value for each head, such that for a write process the controller closes the switch
28 to inject the dither signal into the read-back signal for each head, and for a read
29 only process the controller opens the switch.

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1 30. The data storage device of claim 23, wherein the controller is
2 configured to detect a block error in writing a data block on a section of the
3 media, and in response, re-write that data block.

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5 31. The data storage device of claim 30, wherein the controller re-
6 writes that data block on a different section of the media.

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8 32. The data storage device of claim 30, wherein the controller re-
9 writes that data block using a different head.

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11 33. The data storage device of claim 30, wherein the controller re-
12 writes that data block on a different section of the media with a different head.

13

14 34. The data storage device of claim 23, wherein the data storage
15 device comprises a tape library including a plurality of tape drives including
16 multiple transducer heads, and the recording media comprises magnetic tapes.

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18 35. A data storage device manufactured according to of claim 1.

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20 36. A data storage device manufactured according to steps of claim 12.